Associate Editor: Paul Sorace, M.S., FACSM, ACSM-CEP, CSCS

Exercise Training with Cystic Fibrosis-Related Diabetes

by Alexios Batrakoulis, Ph.D., FACSM, ACSM-EP, ACSM-CPT, EIM, CSCS;
Paul Sorace, M.S., FACSM, ACSM-CEP, CSCS; and Tom LaFontaine, Ph.D., FACSM, ACSM-CEP, CSCS

INTRODUCTION

Cystic fibrosis-related diabetes (CFRD) is a complication of cystic fibrosis (CF) and is associated with increased morbidity and mortality in individuals with CF (1). This condition is a result of abnormal glucose metabolism, which is characterized by insulin deficiency and intermittent insulin resistance. It is important to recognize the early signs and symptoms of abnormal glucose metabolism in individuals with CF to diagnose CFRD. Early diagnosis and treatment correlate with slower rates of pulmonary decline and improved growth (1,2).

CFRD is caused by a buildup of thick mucus secretions in the pancreas that damage the beta islet cells that produce insulin. Insulin helps glucose leave the blood and enter cells, so when it does not function or is not regulated properly, blood glucose levels can increase or decrease. Cystic fibrosis-related diabetes is different from type 1 (T1D) and type 2 diabetes (T2D), but it shares some characteristics with both (2,3). This column will discuss the benefits exercise and physical activity can have on CFRD.

EPIDEMIOLOGY AND PATHOPHYSIOLOGY

CF affects more than 30,000 people in the United States and 80,000 people worldwide (4). This life-threatening genetic disorder causes a buildup of thick, viscous mucus secretions in various organ systems, most commonly the pulmonary, gastrointestinal, and genitourinary systems (4). CF occurs in about 1 of 3,500 births per year in Whites and Northern Europeans. Although CF is a multiorgan disease, its effects on the pulmonary system are the leading cause of patient morbidity and mortality (4).

CF is caused by a mutation in the CF transmembrane conductance regulator (CFTR) gene. The CFTR protein produced by this gene regulates the movement of chloride and sodium ions across epithelial cell membranes (4). When mutations occur in one or both copies of the gene, ion transport is defective leading to respiratory insufficiency, along with many other systemic obstructions and abnormalities (4). Some common overt signs and symptoms of CF include recurrent wheezing or pneumonia, dyspnea on exertion, chronic cough, sputum production, and abdominal distension. Persons with CF also are prone to respiratory and other infectious diseases. Table 1 summarizes medical therapy for individuals with CFRD.

CFRD has been recognized as a unique form of diabetes though it does share some common features with T1D and T2D (6). As opposed to T1D, CFRD is not an autoimmune disorder (4). CFRD occurs in about 40% to 50% of adults and 20% of children with CF (4). In T1D, progression to complete insulin deficiency is the norm. In CFRD, progression toward insulin deficiency is slower and incomplete (6).

The earliest detectable glycemic abnormality is postprandial hyperglycemia that progresses into fasting hyperglycemia (7). CFRD is difficult to treat due to the high caloric needs of persons with CF. Treatment for CFRD includes insulin replacement and a hypercaloric and high-protein diet that does not restrict carbohydrates, fats, or salt, and diabetes self-management education (7). Exercise training, aerobic, and strength training should be incorporated into the treatment plan for CF and CFRD. Patients with CF with or without CFRD need to remain hydrated.

Dietary recommendations for adults with CFRD suggest a daily caloric goal of 1.2- to 1.5-fold greater than a healthy counterpart (6). The only recommended dietary changes at diagnosis of CFRD are to learn carbohydrate counting for insulin dosing if mealtime dosing is implemented (6).

EXERCISE BENEFITS

Integrating structured exercise into the daily routine of individuals with CFRD presents a significant challenge. However, the practice of exercise in the context of CFRD has been linked to a multitude of benefits, including enhancements in both physical and psychological well-being. It is noteworthy that patients with CFRD who exhibited higher levels of physical fitness demonstrated superior survival rates compared to their less active counterparts (8). Considering that people with CFRD are prone to being sedentary, cardiorespiratory and muscle-strengthening activities induce positive alterations in their exercise-capacity muscular fitness, cardiopulmonary function, and health-related quality of life (5). Importantly, the current evidence suggests that exercise training does not have a significant impact on improving pulmonary function; however, there is a possibility that it may have a protective effect (9). Individuals with CFRD are at risk of progressive lung disease, which has the potential to adversely affect pulmonary function and result in ventilatory limitation and dyspnea. Consequently, arterial hypoxemia and carbon

Copyright © 2025 American College of Sports Medicine. Unauthorized reproduction of this article is prohibited.

TABLE 1: Pharmacological Treatment Options for CFRD (5)

Drug Class	Side Effects	Effects on Exercise
Inhaled hypertonic saline	Cough, sore throat, chest tightness	No adverse effects
Inhaled antibiotics	Cough, sore throat, chest tightness, fever, bloody, runny or stuffy nose	No adverse effects
Recombinant deoxyribonuclease	Change in or loss of voice, throat discomfort, skin rash	No adverse effects
Cystic fibrosis transmembrane regulator gene potentiator	Dizziness, headache, body aches, abdominal or chest pain, cough, nasal congestion	No adverse effects
Pancreatic enzymes		No adverse effects

dioxide retention are prevalent among this population when engaging in exercise (10). Moreover, no strong evidence regarding the role of exercise training in reducing hospitalization and healthcare utilization is available (9).

EXERCISE TESTING

According to the current guidelines, an exercise test should be a part of the annual assessment for CFRD patients. The utilization of exercise testing has the potential to play a pivotal role in the evaluation of an individual's capacity for exercise and the customization of individual-specific exercise programs. Furthermore, an exercise test has been demonstrated to provide patients with CFRD and their families with the opportunity to gain empowerment and liberation through the process of being shown that an individual with CFRD can exercise safely (11). The gold standard for assessing cardiopulmonary fitness is cardiopulmonary exercise testing (CPET), a laboratory-based maximal test that provides precise exercise data. However, CPET is a costly, equipment-intensive procedure that requires the expertise of a trained professional (*i.e.*, clinical exercise physiologists or other qualified healthcare providers) to supervise and interpret the test results. Thus, it is recommended that exercise professionals consider a number of field tests, including the 6-minute walk test, incremental 20-m run, 10-m walk shuttle tests, 3-minute step test, incremental step test, treadmill, and cycle ergometry tests (ramped protocols) (11). It is not currently recommended to perform specific strength and flexibility tests in patients with CFRD, given that aerobic training is the primary focus. However, standard muscular fitness assessment tests (*e.g.*, 30-second chair stand test and modified sit and reach test) that are commonly utilized in individuals with diabetes can be employed. Additionally, the initial evaluation should encompass an assessment of the client's posture and neuromuscular control, with a particular focus on the trunk muscles (5).

EXERCISE RECOMMENDATIONS

The exercise guidelines utilized for individuals with chronic obstructive pulmonary disease or T2D are widely applicable to those with CFRD before and after lung transplantation, provided that modifications are adapted to the individual's exercise tolerance (5,8,10). Combined aerobic and resistance training appears to be the optimal exercise strategy for people living with impaired lung function and metabolic derangements commonly observed in CFRD (8,12–14). In particular, combined training showed a significant increase in aerobic and anaerobic capacity, improved pulmonary function, and strengthened ventilatory muscles (5,10). The large majority of exercise training studies in CFRD have focused on cardiorespiratory fitness activities, indicating meaningful changes in lung function, maximal aerobic capacity, dyspnea, and quality of life in home-based or hospital-based settings (15,16). Noteworthy, the extant evidence indicates that there are no meaningful differences in maximal aerobic capacity between individuals with and without CFRD when they engage in comparable levels of physical activity (17).

Muscle-strengthening activities exhibited favorable effects on muscular strength, muscular endurance, and lean body mass. Progressive resistance training with an emphasis on postural muscles and joint mobility training in areas of limited range of motion are of paramount importance for this population (5). Moderate-intensity exercise promotes the inhibition of luminal sodium conductance, resulting in an increase in the water content of the mucus within the lung during exercise, which could explain the advantageous effects of exercise observed in patients with CFRD (18). The early training of neuromuscular abilities in conjunction with sports practice may prove beneficial for youth with a mild disease profile. In particular, integrative neuromuscular training, which incorporates progressively loaded fundamental movement patterns and basic drills for enhancing motor skills into an exercise session, has been demonstrated to enhance general preparedness for sports in children and adolescents with CFRD (19). This is important because a well-designed, injury-free, and science-based resistance training program has the potential to enhance and prolong cardiorespiratory function,

Copyright © 2025 American College of Sports Medicine. Unauthorized reproduction of this article is prohibited.

TABLE 2: Aerobic Training Recommendations for Individuals With CFRD

Training Parameter	Recommendation
Frequency	3–5 days per week and progressively increase to 5–7 days
Intensity	40%–50% and progressively increase to 60%–70% HRR (RPE 11–14/20 or 4–6/10)
Time	20–30 minutes (progressively to 40–60 minutes) per day
Type	Treadmill- or free-walking and stationary cycling

HRR indicates heart rate reserve.
(5,8,10,12)

TABLE 4: Flexibility Training Recommendations for Individuals With CFRD

Training Parameter	Recommendation
Frequency	1–3 days per week
Intensity	Stretch to the point of feeling tightness or slight discomfort.
Time	10–30 seconds (progressively to 30–60 seconds) hold 1–2 (progressively to 3–4) repetitions 1 exercise per major muscle group.
Type	Static stretching

(5,8,10,12)

glycemic control, and quality of life for children and adolescents with CFRD (20). Tables 2, 3, and 4 summarize exercise recommendations for individuals with CFRD.

SPECIAL CONSIDERATIONS

- Exercise professionals serving clients with CFRD should consider diabetes-related limitations and contraindications (*e.g.*, hypoglycemia, preexercise optimal blood glucose levels, continuous or frequent glucose monitoring during exercise, the timing of exercise, and availability of glucose tablets or other rapid-acting carbohydrates) as directed by the client's physician or other healthcare professional.
- Individuals with CFRD require extensive warm-up and cool-down periods, given that they engage in fewer hours of vigorous physical activity than their healthy counterparts.
- Proper hydration is critically important for persons with CFRD because they are at risk of severe dehydration from exercise due to the elevated levels of sodium chloride in their sweat.
- Respiratory rate, oxygen saturation, and rating of perceived exertion (RPE) should be monitored closely in individuals with CFRD during supervised exercise.
- Clients with CFRD should be instructed to determine intensity during an exercise session, using the RPE scale due to ventilatory limitations and fluctuating health status.
- Exercise should be terminated if the RPE/OMNI-RES value reaches 7 on a 0 to 10 scale.
- The exercise intensity should be modified to allow for a minimum of 30 minutes of aerobic activity within the recommended target heart zone.
- Aerobic exercise may be more suitable for individuals with advanced disease.
- Individual preferences are a crucial factor in the selection of exercise training modalities.

(5,8,10,12,21)

TABLE 3: Resistance Training Recommendations for Individuals With CFRD

Training Parameter	Recommendation
Frequency	2–3 nonconsecutive days per week
Intensity	40%–50% 1-RM (progressively increase to 60%–70%) OMNI-RES 2–3/10 (progressively increase to 4–5/10)
Time	1–2 sets × 12–15 (progressively to 8–12) repetitions (nonfailure) 1–2 exercises per muscle group 2–3 minutes (progressively to 1–2 minutes) rest between sets
Type	Stationary weight machines, dumbbells, elastic bands, or bodyweight movements.

1-RM indicates one repetition maximum; OMNI-RES, OMNI-resistance exercise scale of perceived exertion.
(5,8,10,12)

Copyright © 2025 American College of Sports Medicine. Unauthorized reproduction of this article is prohibited.

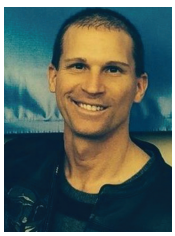
CONCLUSION

The implementation of a personalized exercise program combining aerobic and anaerobic stimuli, tailored to the individual's needs and preferences, is recommended. Such a multicomponent exercise approach should take into account a range of psychophysiological factors to enhance the efficacy of exercise training and foster positive long-term exercise habits in individuals of all ages with CFRD.

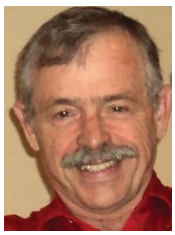
1. Moran A, Pillay K, Becker D, Granados A, Hameed S, Acerini CL. ISPAD Clinical Practice Consensus Guidelines 2018: management of cystic fibrosis-related diabetes in children and adolescents. *Pediatr Diabetes*. 2018;19(Suppl 27): 64–74.
2. Lavie M, Fisher D, Vilozni D, *et al*. Glucose intolerance in cystic fibrosis as a determinant of pulmonary function and clinical status. *Diabetes Res Clin Pract*. 2015;110(3):276–84.
3. Hunt WR, Zughaier SM, Guentert DE, *et al*. Hyperglycemia impedes lung bacterial clearance in a murine model of cystic fibrosis-related diabetes. *Am J Physiol Lung Cell Mol Physiol*. 2014;306(1):L43–9.
4. Brown S, Rachel W, Tobin P. Cystic fibrosis pathophysiology, diagnosis, and treatment. *JAAPA*. 2017;30(5):23–7.
5. Rundell KW, Smoliga JM, Weiss P. Pulmonary disorders and conditions. In: Jacobs PL, editor. *NSCA's Essentials of Training Special Populations*. Champaign (IL): Human Kinetics; 2018. p. 179.
6. Prentice BJ, Potter KJ, Coriati A, *et al*. Cystic fibrosis-related diabetes: clinical approach and knowledge gaps. *Paediatr Respir Rev*. 2023;46:3–11.
7. Alves C, Della-Manna T, Albuquerque CTM. Cystic fibrosis-related diabetes: an update on pathophysiology, diagnosis, and treatment. *J Pediatr Endocrinol Metab*. 2020;33(7):835–43.
8. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription*. 11th ed. Philadelphia (PA): Wolters Kluwer; 2021.
9. Shoemaker MJ, Hurt H, Arndt L. The evidence regarding exercise training in the management of cystic fibrosis: a systematic review. *Cardiopulm Phys Ther J*. 2008;19(3):75–83.
10. Danduran MJ, Camarda L. Cystic fibrosis. In: Ehrman JK, Gordon PM, Visich PS, Keteyian SK, editors. *Clinical Exercise Physiology*. Champaign (IL): Human Kinetics; 2019. pp. 347–70.
11. Urquhart DS. Exercise testing in cystic fibrosis: why (and how)? *J R Soc Med*. 2011;104(Suppl 1(Suppl 1)):S6–14.
12. Reading SA, Stinear JW, Whyte KF. Respiratory diseases. In: Thompson WR, editor. *ACSM's Clinical Exercise Physiology*. 1st ed. Philadelphia (PA): Wolters Kluwer; 2019. pp. 370–422.
13. Al-Mhanna SB, Rocha-Rodriguesc S, Mohamed M, *et al*. Effects of combined aerobic exercise and diet on cardiometabolic health in patients with obesity and type 2 diabetes: a systematic review and meta-analysis. *BMC Sports Sci Med Rehabil*. 2023;15:165.
14. Al-Mhanna SB, Batrakoulis A, Wan Ghazali WS, *et al*. Effects of combined aerobic and resistance training on glycemic control, blood pressure, inflammation, cardiorespiratory fitness and quality of life in patients with type 2 diabetes and overweight/obesity: a systematic review and meta-analysis. *Peer J*. 2024;12: e17525.
15. Schneiderman-Walker J, Pollock SL, Corey M, *et al*. A randomized controlled trial of a 3-year home exercise program in cystic fibrosis. *J Pediatr*. 2000;136(3): 304–10.
16. Turchetta A, Salerno T, Lucidi V, *et al*. Usefulness of a program of hospital-supervised physical training in patients with cystic fibrosis. *Pediatr Pulmonol*. 2004;38(2):115–8.
17. Radtke T, Kriemler S, Stein L, *et al*. Cystic fibrosis related diabetes is not associated with maximal aerobic exercise capacity in cystic fibrosis: a cross-sectional analysis of an international multicenter trial. *J Cyst Fibros*. 2023;22(1):31–8.
18. Hebestreit A, Kersting U, Basler B, Jeschke R, Hebestreit H. Exercise inhibits epithelial sodium channels in patients with cystic fibrosis. *Am J Respir Crit Care Med*. 2001;164(3):443–6.
19. Gruet M, Saynor ZL, Urquhart DS, Radtke T. Rethinking physical exercise training in the modern era of cystic fibrosis: a step towards optimising short-term efficacy and long-term engagement. *J Cyst Fibros*. 2022;21(2):e83–98.
20. Holmes CJ, Granados A. Resistance training recommendations for children and adolescents with cystic fibrosis-related diabetes. *Strength Cond J*. 2022;44(1): 111–8.
21. Batrakoulis A, Jamurtas AZ, Fatouros IG. Exercise and type II diabetes mellitus: a brief guide for exercise professionals. *Strength Cond J*. 2022;44(6):64–72.

Disclosure: *The authors declare no conflict of interest and do not have any financial disclosures.*

Alexios Batrakoulis, Ph.D., FACSM, ACSM-EP, ACSM-CPT, EIM, CSCS, *is an adjunct professor at the University of Thessaly and the Democritus University of Thrace in Greece and a global fitness educator as the founder of the International Obesity Exercise Training Institute. Dr. Batrakoulis currently serves on the NSCA Board of Directors (Personal Trainer Representative) and has served on numerous ACSM and NSCA committees. He also was named the 2018 IDEA Personal Trainer of the Year, 2019 IDEA China Fitness Innovator, 2020 NSCA Personal Trainer of the Year, 2021 PFP Trainer of the Year, and 2022 ACSM Certified Professional of the Year.*



Paul Sorace, M.S., FACSM, ACSM-CEP, CSCS, *is a clinical exercise physiologist in New Jersey. He is an associate editor for* ACSM's Health & Fitness Journal® *and the clinical associate editor for* ACSM's Certification Review, *4th and 5th editions. Paul also has served on numerous ACSM Committees, including chair of the CCRB Publications Subcommittee.*



Tom LaFontaine, Ph.D., FACSM, ACSM-CEP, CSCS, *has been a member of ACSM since 1975 and is currently a fellow emeritus member. He is coauthor of* The Exercise Professional's Guide to Optimizing Health: Strategies for Preventing and Reducing Chronic Disease, *a textbook published in cooperation with ACSM and has authored several articles published in ACSM journals. He also has served on several ACSM committees.*

Copyright © 2025 American College of Sports Medicine. Unauthorized reproduction of this article is prohibited.